gasmet

SOLVING AIR QUALITY ISSUES

Utilizing the power of FTIR

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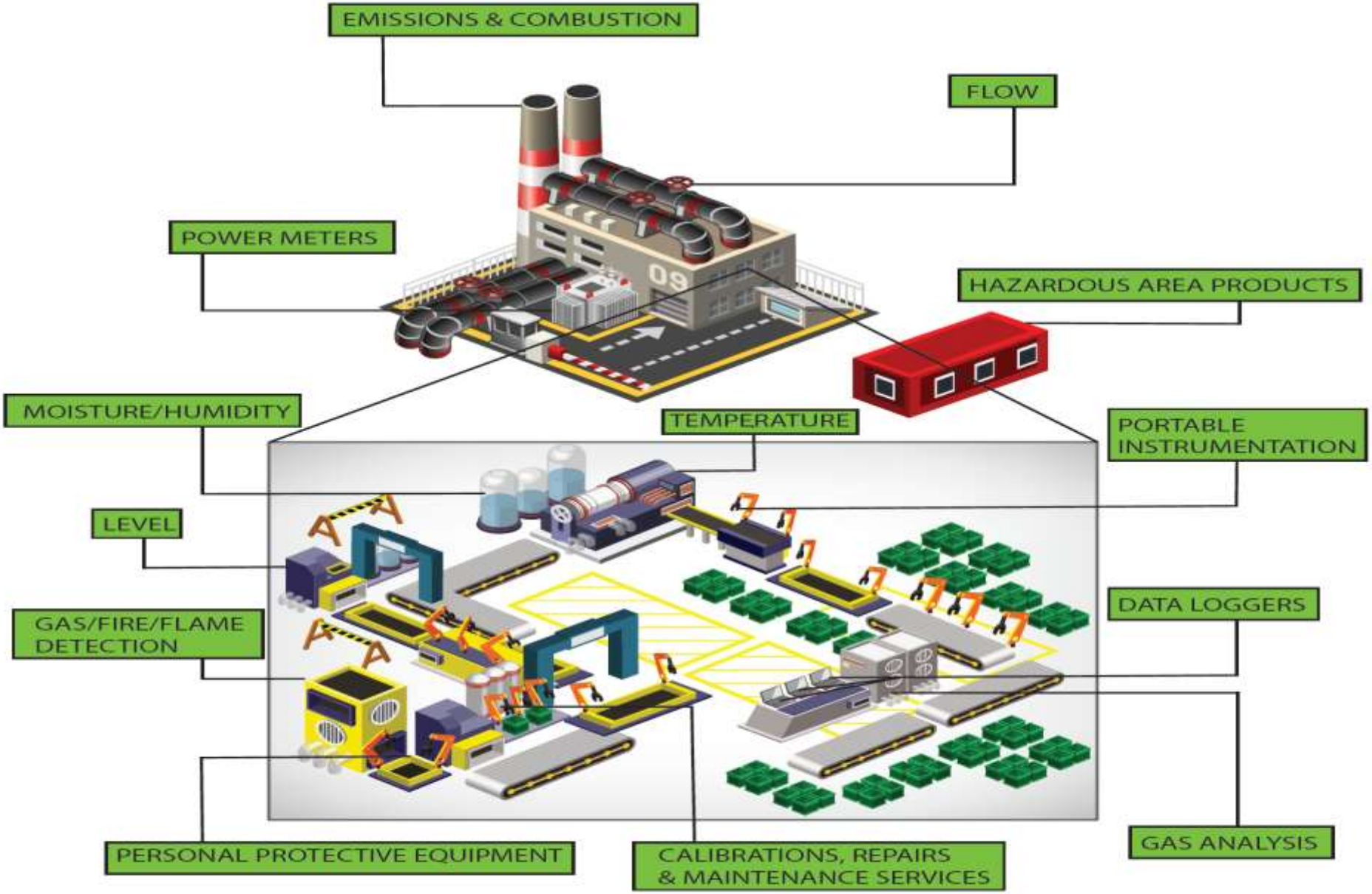
Martech Controls martechcontrols.com

iFacilityServices iFacilityServices.com

One Call. One Company.



All your process, facility and safety needs in one place.

Product Categories:
On-Line Analyzers - For gases and liquids. Technologies: electrochemical, catalytic, infrared, spectroscopy, spectrometry, chromatography, fourier transform infrared.
Process Control and Measurement - Flow, pressure, temperature, humidity, moisture, prowe, level.
Instrumentation - Gas detection, sound, noise, dust, iaq, calibration gases and regulators.
Safety Equipment - Personal protective equipment, fall protection, first aid, spill control
Calibration and Repair Services – to ISO 17025 standards
- On-site or in our state of the art calibration lab
- Calibration and repair of portable and fixed instruments
- Respirator maintenance - SCBA, PAPR, airline, breather boxes
- Level A suit testing - to ASTM F 1052 Pressure Test Method
- Fall protection equipment inspection - Competent Person Fall Protection

Safety equipment and portable instruments: Safety Inc www.ESafetyInc.com

Process Instrumentation :
- New England ***ETA Process Instrumentation*** www.etapii.com
- Upstate NY ***Martech Controls www.*** martechcontrols.com

Calibration and Repair services: ***iFacility Services*** www.iFacilityServices.com

Agenda

1. FTIR technology overview
2. Applications /Case Studies
3. Q & A’s

FTIR (Fourier Transform InfraRed) gas analyzers identify and measure gaseous compounds by their absorbance of infrared radiation.

This is possible because every molecular structure has a unique combination of atoms, and therefore produces a unique absorption spectrum when exposed to infrared light.

Instrumental analysis of the mid-IR spectrum (2 to 12 micrometer wavelength) enables the qualitative identification and quantitative analysis of the gaseous compounds in the sample gas.

FTIR analyzers are able to simultaneously measure multiple analytes in complex gas matrices, detecting virtually all gas-phase species (both organic and inorganic, except diatomic elements N_2, O_2 etc. and noble gases He, Ne, etc.).

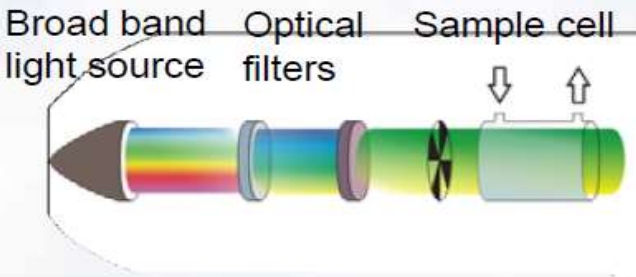
For example, the Gasmet FTIR gas analyzer collects a complete infrared spectrum (a measurement of the infrared light absorbed by molecules inside the sample gas cell) 10 times per second.

Multiple spectra are co-added together according to a selected measurement time (improving accuracy by raising the signal-to-noise ratio). The actual concentrations of gases are calculated from the resulting sample spectrum using a patented modified **Classical Least Squares analysis algorithm**.

IR Technologies

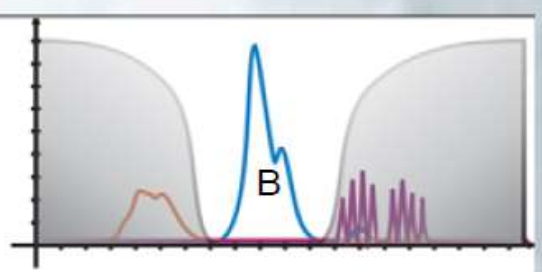
- **Non-Dispersive IR** instruments (NDIR) measure only separate wavelength bands, no information from other parts of the spectrum

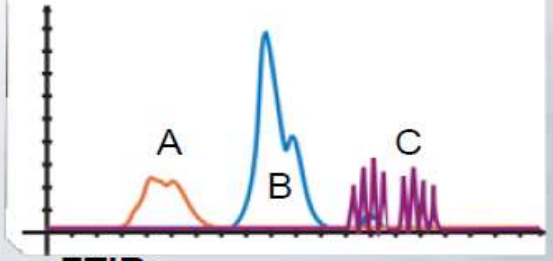
- **Fourier Transform Infrared** (FTIR) spectrometer measures all the IR wavelengths simultaneously and produces a full spectrum.



Interferometer

NDIR:
Only one component can be analysed from a single Measurement and interference cannot be compensated





FTIR:
All components can be analysed from single measurement and interferences are resolved

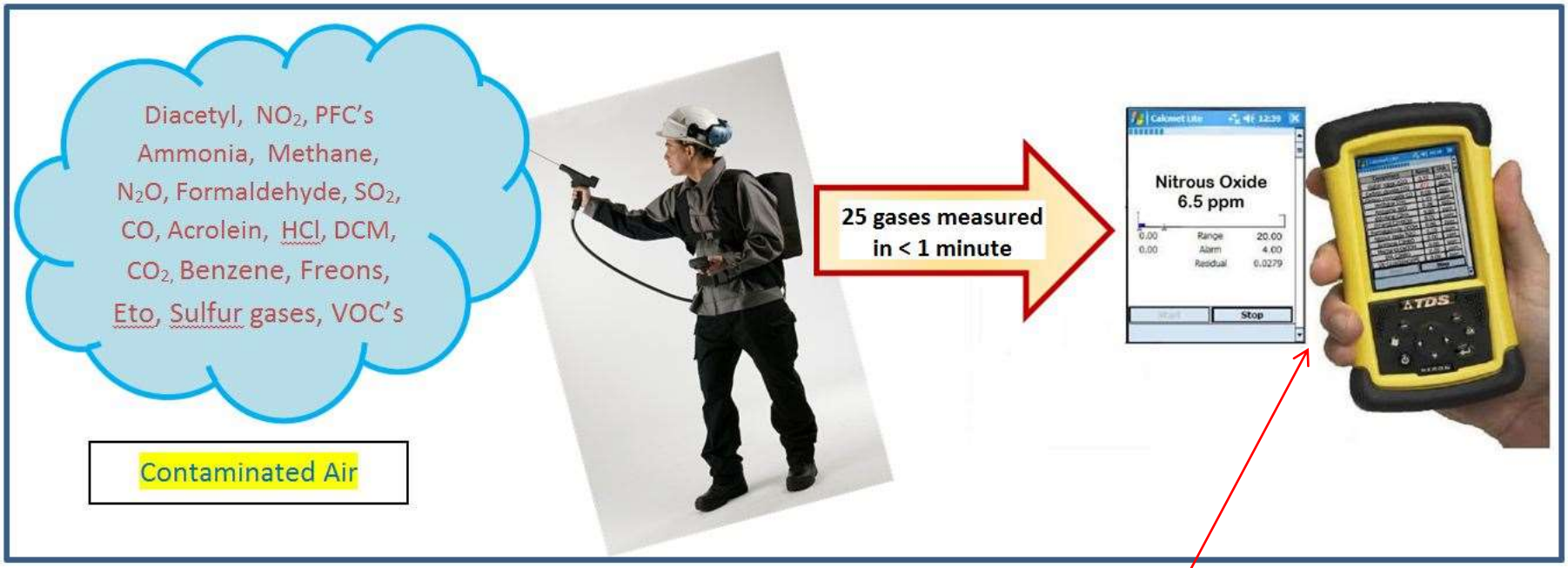
FTIR	NDIR
50, 200 or 600 readings per analysis based on selectable 5, 20, or 60 sec interval (10 readings/sec)	1 reading per analysis Measures a single wavelength with variable filter in mid-IR range
• 473 data points /scan	~ 26 data points / scan
• 25 with Configuration 1 PDA • 50 with Configuration 2 Laptop	• Up to 5 gases IF all gases are known and IF gases are not similar enough to cause cross interference

0.090 ppm	Formaldehyde	0.11 ppm
0.011 ppm	Benzene	2 ppm
0.004 ppm	Sulphur Hexafluoride	0.010 ppm
0.017 ppm	Ethylene Oxide (Eto)	0.350 ppm
0.130 ppm	Ammonia (NH3)	0.700 ppm
0.300 ppm	Hydrogen Fluoride (HF)	not available
0.010 ppm	Freon 134a	0.170 ppm

Any unknown gas identified in the sample can be analyzed and identified with software	Can't identify if an unknown gas is present if that gas is not loaded in the library on the instrument

No cross interference.	**Cross interference** - like gases can't be speciated
Fixed mirror provides extreme stability, no need for annual adjustment **Can be used and calibrated in any position.** **Ready for use in less than 1 minute** **No in-line chemical filter needed, only a particulate filter** **Unaffected by temperature, humidity, or pressure changes**	**Adjustable mirrors typically require factory service at annual calibration.** **Sensitive to orientation – calibrating in one position and using in another changes the readings** **Warm up time before accurate readings of 20- 30 minutes** **Requires use of in-line charcoal filter, filter must be routinely changed, no way to know if there is filter breakthrough** **Need to choose compensation for changes in temperature, pressure, or humidity**
Rhodium coated lens impervious to corrosive chemicals	**Corrosive chemicals degrade windows, eventually requiring costly replacement**
Never requires a factory calibration. Internal laser is used as calibration reference with every measurement.	**Annual factory calibration recommended, typically also includes adjustment of mirrors, $ 1500-2000 per year, more for larger libraries**
Accuracy : ± 2% of reading **Precision is 0.01%** **Zero drift stability : ± 2% smallest measuring range per zero-point calibration interval**	**± 10 – 25 % of reading** • **Quoted accuracy is based on only a single gas, doesn't take into account cross interference issues that cause inaccurate readings.**

Understanding the power of FTIR[1] gas analysis



FTIR Gas Analysis using a combination of optical light measurement and a mathematical algorithm to measure many gases and their concentrations simultaneously.

25 gases chosen & changed from a master library **(335 gases).**

Never needs recalibration

1. FTIR = Fourier Transform Infrared

The FTIR Gas Analyzer

Interferometer

Compact – Rugged
Fast scanning
Vibration insensitive

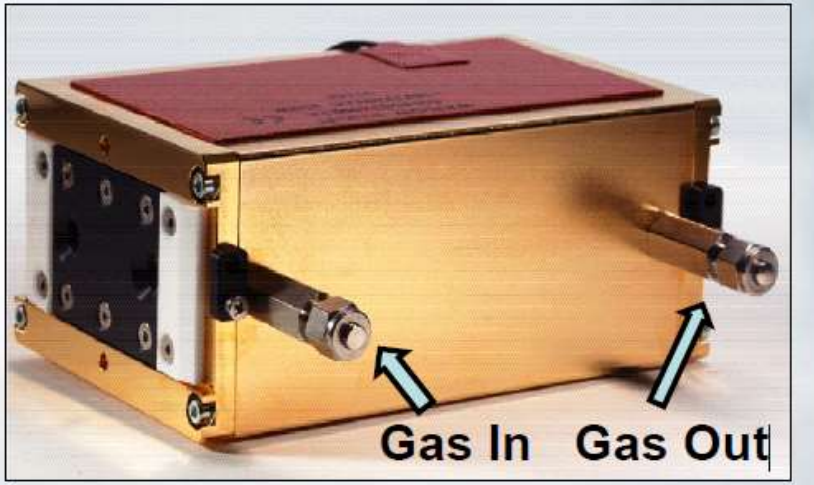
Gas Cell

Corrosion resistant sample cell
Nickel-rhodium-gold plated

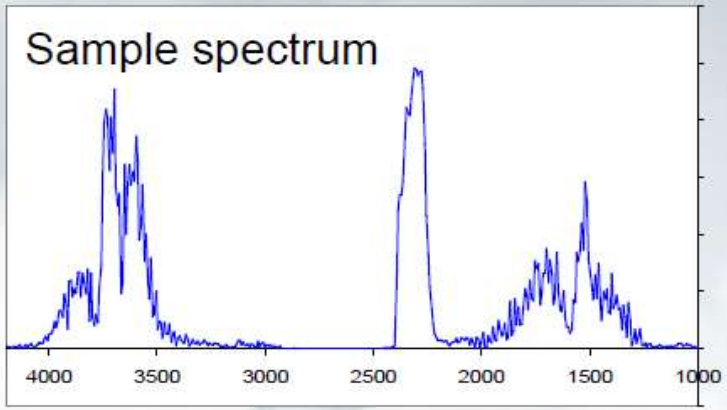
Corrosion resistant sample cells

- **Inert -** Nickel-rhodium-gold plated mirrors & aluminium cell body
- **Fixed mirrors** (resilient to shocks & bumps of handling & transporting)
- Same **rugged tough gas cell** used in CEMS as ambient application
- Absorption to 9.8 m Single pass and multi-pass (White cell)
- Cell windows (ZnSe, immune to water vapour)
- **Gas Measurement Range** :

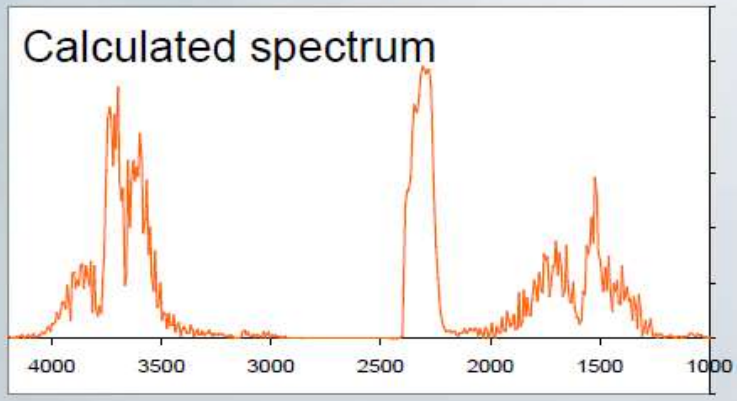
  Sub-ppm to % levels



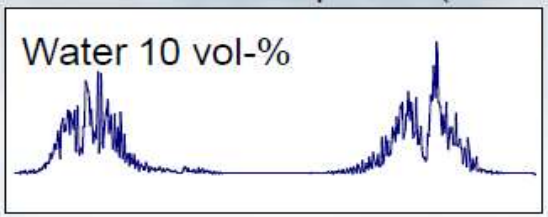
Real IR spectra:

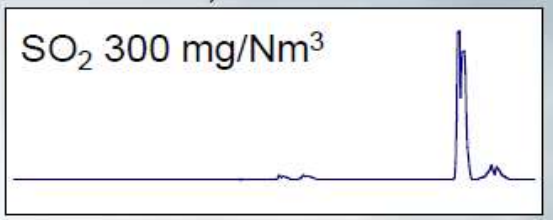


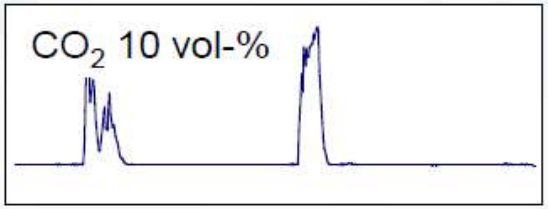
CALCMET Analysis:
0.881 * Water 10 vol-%
1.112 * CO_2 10 vol-%
0.995 * CO 1000 mg/Nm^3
0.910 * NO 300 mg/Nm3
0.810 * SO_2 300 mg/Nm3
0.660 * NH_3 100 mg/Nm^3
0.082 * HCl 50 mg/Nm^3
0.210 * Methane 50 mg/Nm^3

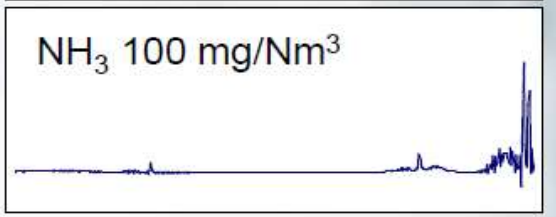


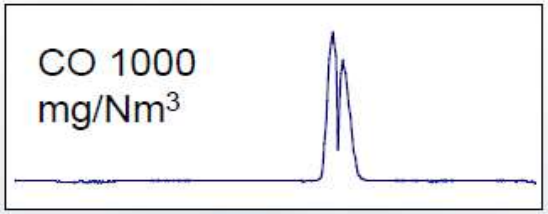
Reference Spectra (not to same scale):

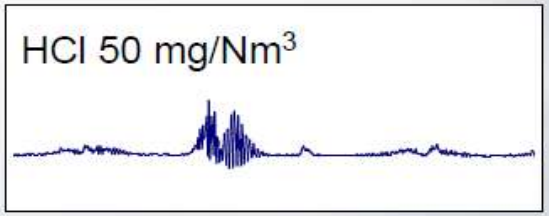


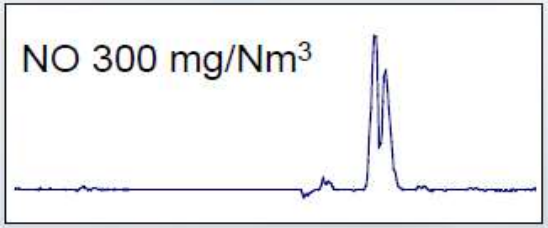


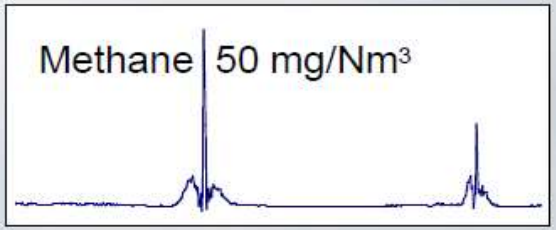








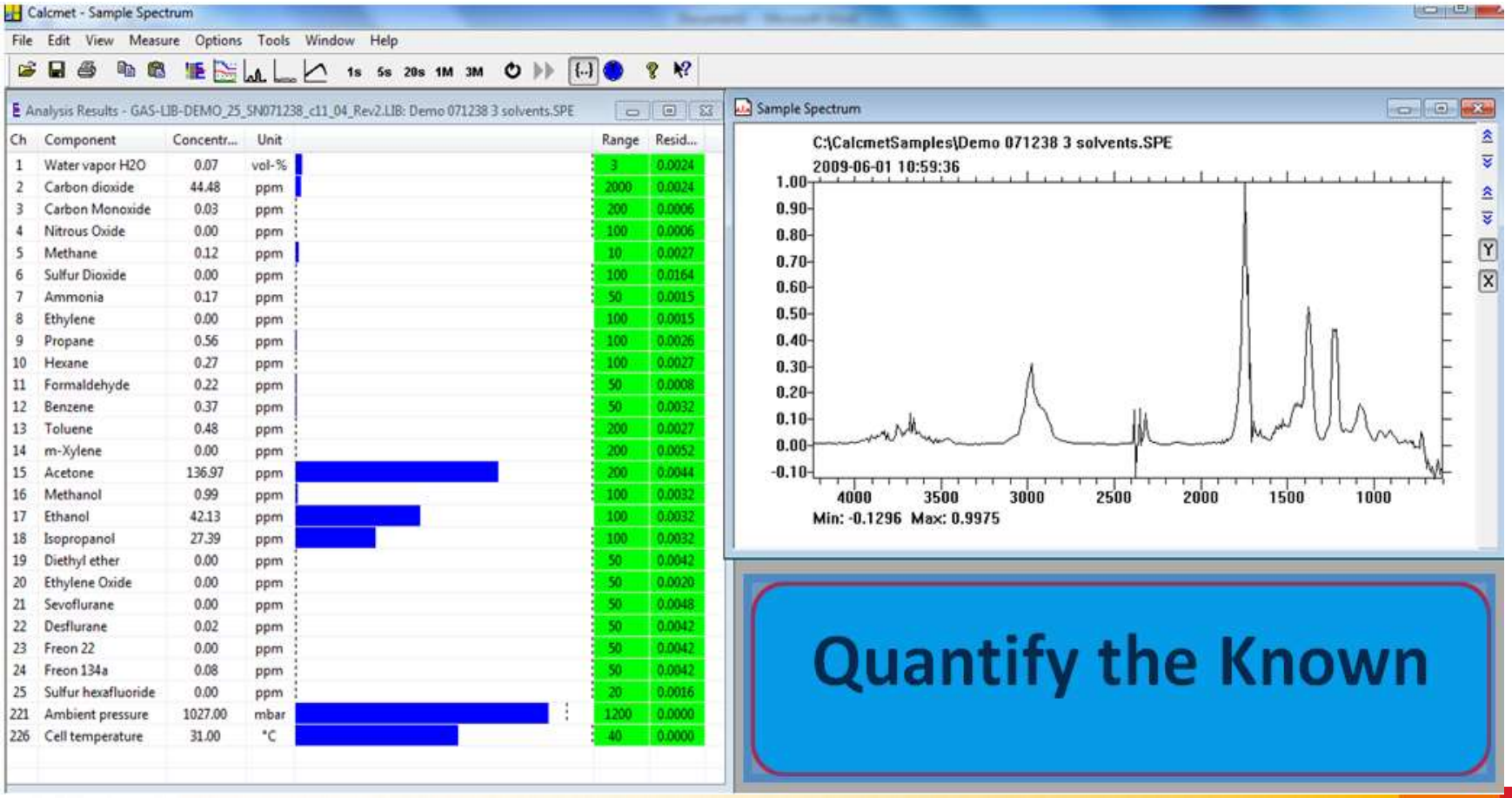




Concentrations:				
Water	8.81 vol-%	SO_2	243 mg/Nm^3
CO_2	11.12 vol-%	NH_3	66.0 mg/Nm^3
CO	955 mg/Nm^3	HCl	4.1 mg/Nm^3
NO	274 mg/Nm^3	Methane	10.5 mg/Nm^3

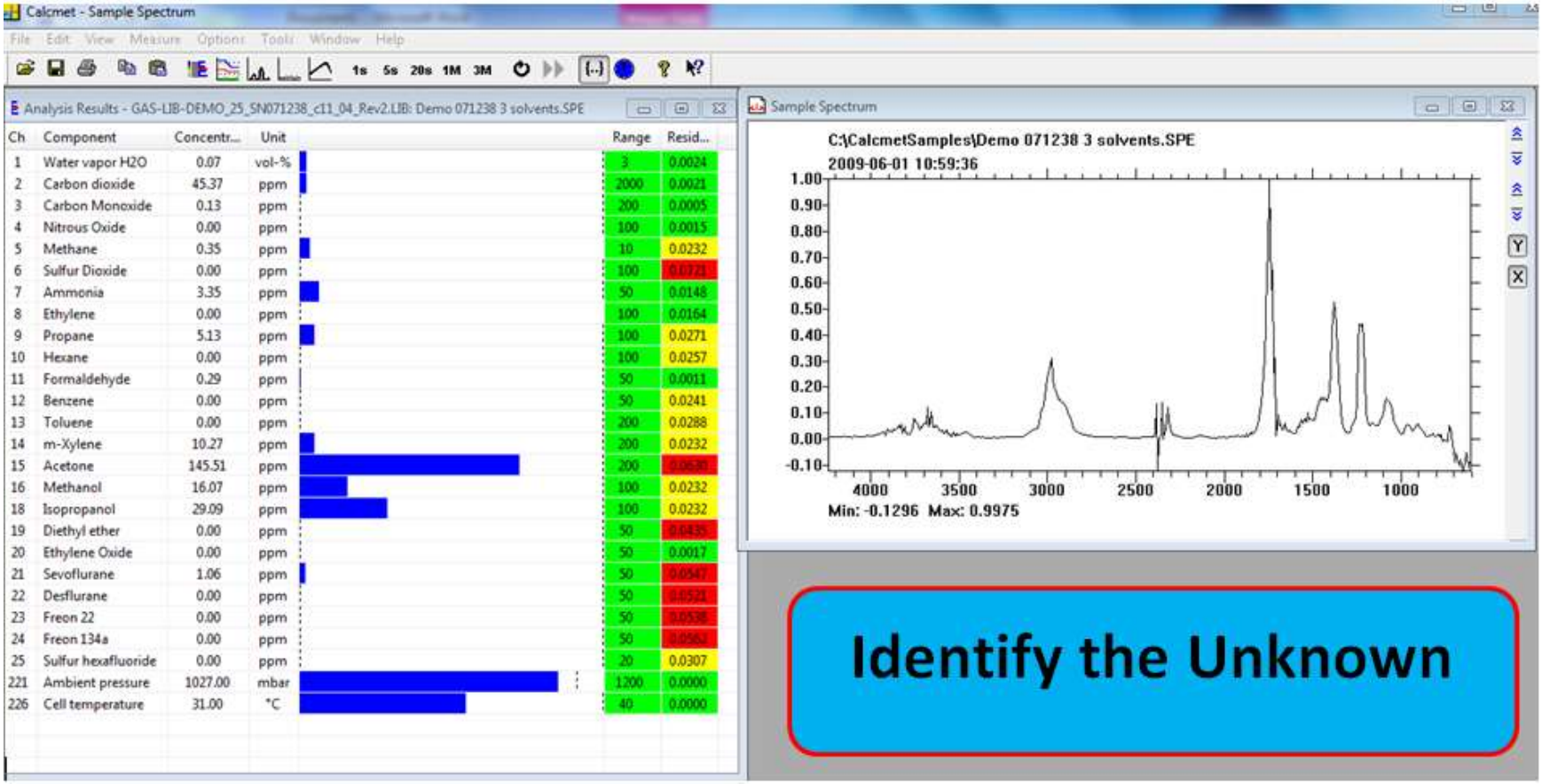
A. Dual Functionality of FTIR

QUANTIFYING THE KNOWN



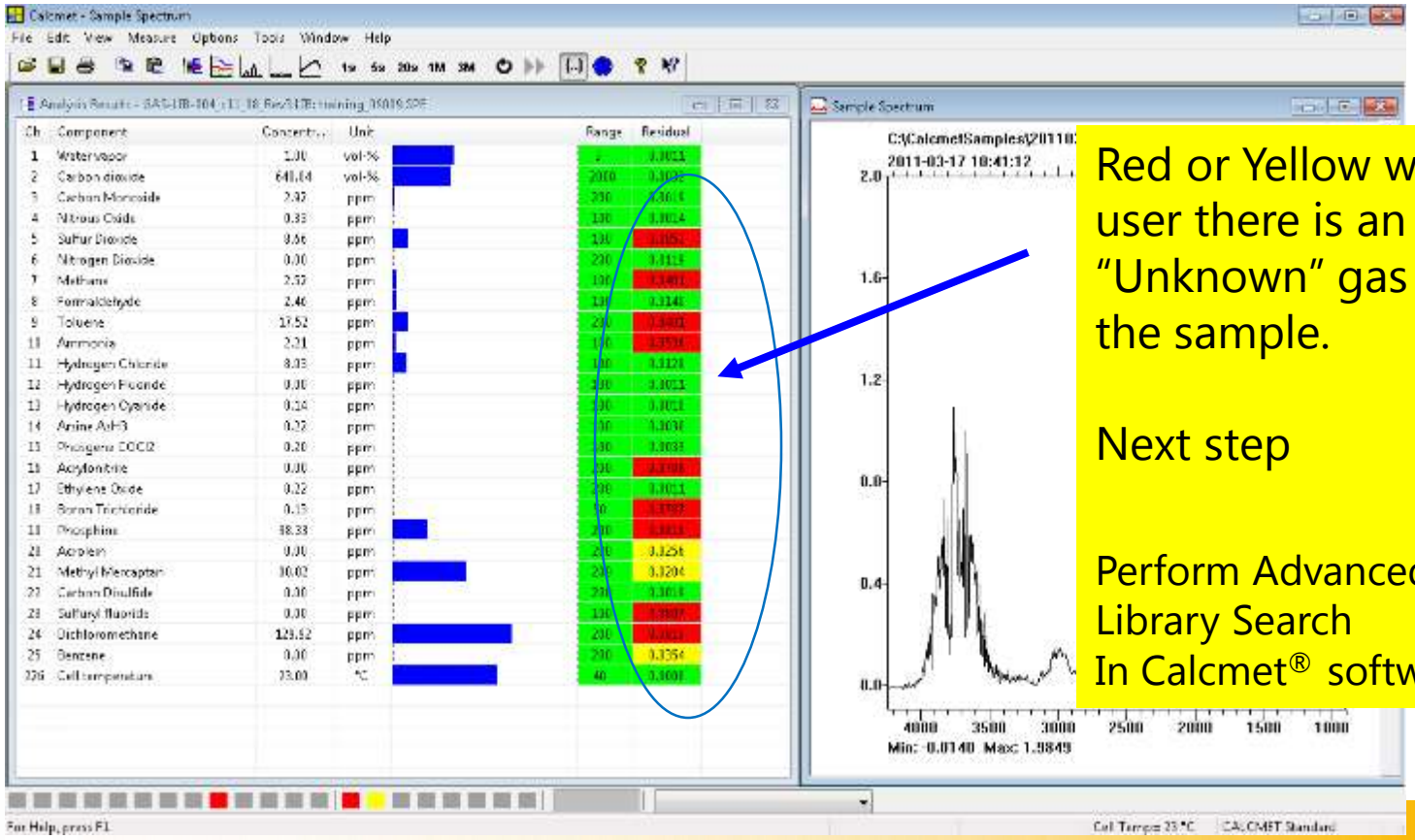
B. Dual Functionality of FTIR

IDENTIFYING THE UNKNOWN



CALCMET™ ADVANCED LIBRARY SEARCH

Identification of unknown gases



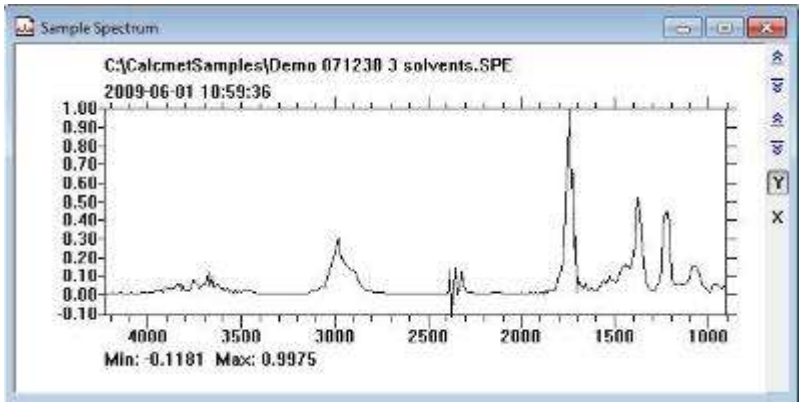
Red or Yellow warns user there is an "Unknown" gas in the sample.

Next step

Perform Advanced Library Search In Calcmet® software

IDENTIFYING “UNKNOWN” GASES

The Power & Speed of FTIR !



Advanced Library Search

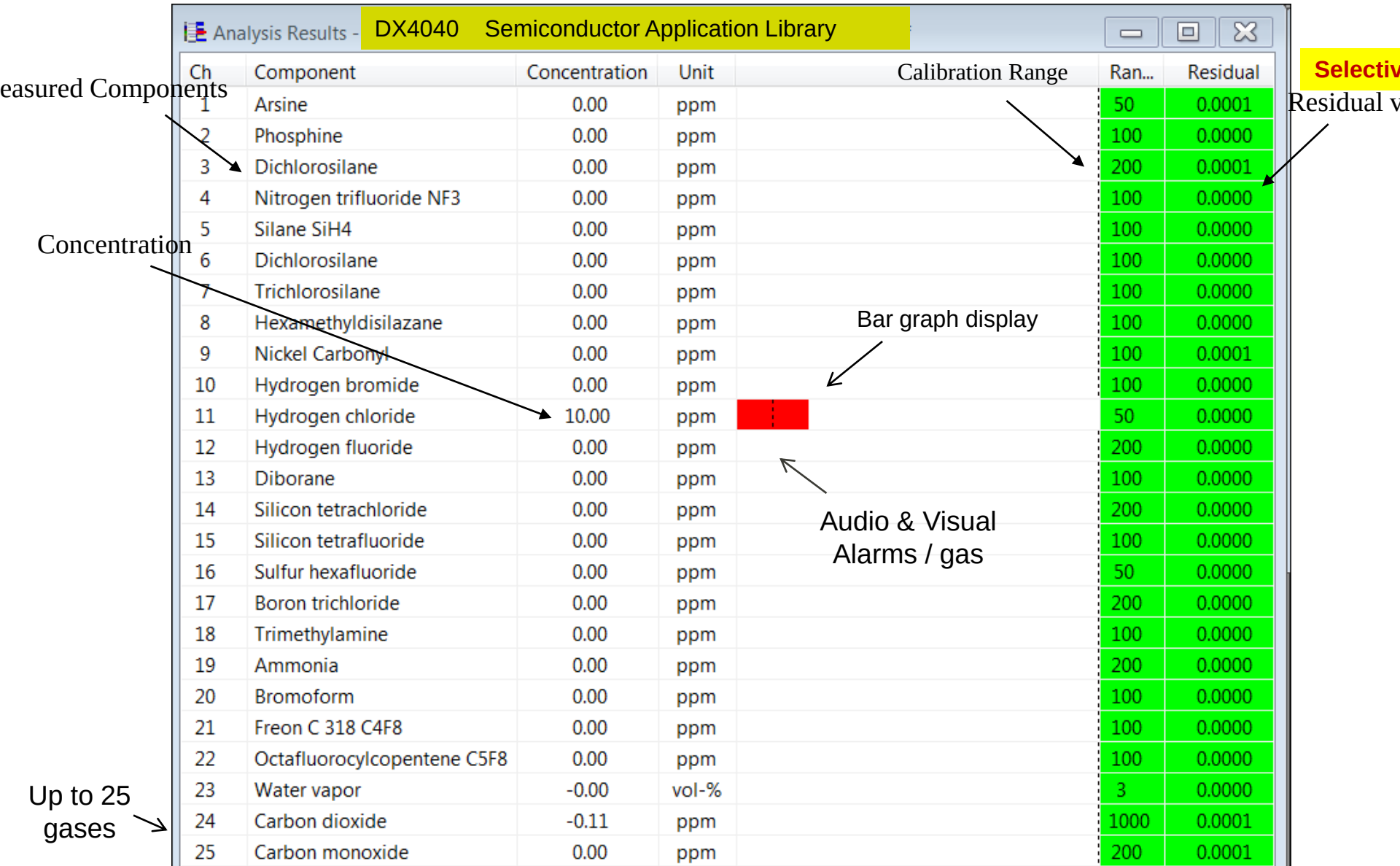
Search Reference Library, over 350+ gases

Search NIST/EPA Library, over 5000 gases

Library Search Results - 2009-06-01 10:59:36 C:\CalcmetSamples\Demo 071238 3 solvents.SPE

Library	Component	Fit	Concentration
Librarysearch.LIB	Acetone C3H6O	97.46	144.58
Librarysearch.LIB	Ethanol C2H5OH	96.09	41.52
Librarysearch.LIB	Isopropanol C3H8O	93.86	26.02

FTIR = SIMULTANEOUS MULTI-GAS READINGS (25)



Ch	Component	Concentration	Unit	Calibration Range	Ran...	Residual
1	Arsine	0.00	ppm		50	0.0001
2	Phosphine	0.00	ppm		100	0.0000
3	Dichlorosilane	0.00	ppm		200	0.0001
4	Nitrogen trifluoride NF3	0.00	ppm		100	0.0000
5	Silane SiH4	0.00	ppm		100	0.0000
6	Dichlorosilane	0.00	ppm		100	0.0000
7	Trichlorosilane	0.00	ppm		100	0.0000
8	Hexamethyldisilazane	0.00	ppm		100	0.0000
9	Nickel Carbonyl	0.00	ppm		100	0.0001
10	Hydrogen bromide	0.00	ppm		100	0.0000
11	Hydrogen chloride	10.00	ppm		50	0.0000
12	Hydrogen fluoride	0.00	ppm		200	0.0000
13	Diborane	0.00	ppm		100	0.0000
14	Silicon tetrachloride	0.00	ppm		200	0.0000
15	Silicon tetrafluoride	0.00	ppm		100	0.0000
16	Sulfur hexafluoride	0.00	ppm		50	0.0000
17	Boron trichloride	0.00	ppm		200	0.0000
18	Trimethylamine	0.00	ppm		100	0.0000
19	Ammonia	0.00	ppm		200	0.0000
20	Bromoform	0.00	ppm		100	0.0000
21	Freon C 318 C4F8	0.00	ppm		100	0.0000
22	Octafluorocylcopentene C5F8	0.00	ppm		100	0.0000
23	Water vapor	-0.00	vol-%		3	0.0000
24	Carbon dioxide	-0.11	ppm		1000	0.0001
25	Carbon monoxide	0.00	ppm		200	0.0001

FTIR _ SENSITIVITY (MDL'S)

BASED ON 1 MINUTE SAMPLING (600 READINGS) IN NITROGEN

1. Acrolein – (0.13 ppm)
2. Acrylonitrile - (0.18 ppm)
3. Ammonia - (0.07 ppm)
4. Arsine - (0.01 ppm)
5. Benzene - (0.07 ppm)
6. Boron trichloride – (0.005 ppm)
7. Carbon dioxide – (< 10 ppm)
8. Carbon monoxide – (0.12 ppm)
9. Carbon disulfide - (0.09 ppm)
10. Dichloromethane – (0.06 ppm)
11. Ethylene oxide - (0.08 ppm)
12. Formaldehyde – (0.04 ppm)
13. Hydrogen chloride – (0.10 ppm)
14. Hydrogen cyanide – (0.17 ppm)
15. Hydrogen fluoride – (0.15 ppm)
16. Methane - (0.03 ppm)
17. Methyl mercaptan – (0.21 ppm)
18. Nitrogen dioxide – (0.19 ppm)
19. Nitrous oxide – (0.01ppm)
20. Phosgene – (0.01 ppm)
21. Phosphine – (0.10 ppm)
22. Sulfur dioxide – (0.02 ppm)
23. Sulfuryl fluoride – (0.02 ppm)
24. Toluene – (0.06 ppm)
25. Water Vapour

Sub-ppm / ppb gas dependent

What can’t be measured with FTIR technology

All gases absorb mid-IR wavelengths except:

- **diatomic homonuclear molecules such as O2, N2, H2, Cl2, F2,**

- **The noble gases (He, Ne, Ar..) & “H2S” is a very weak IR absorber**

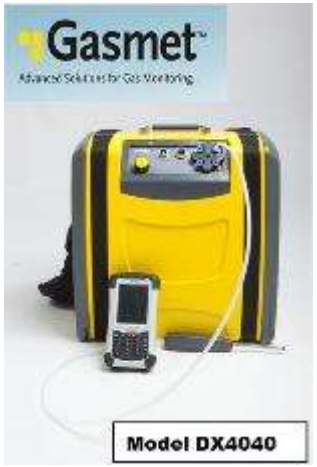
FTIR Gas Analyzer can rapidly assess site safety & exposure risk

- **Natural Gas leaks** at low levels (Methane (ppm) & Mercaptans)
- Toxics at Clandestine Lab. clean up site
- Measuring for the presence of **Freons** at industrial sites
- **Acid gases** such as **HCl, HF** and **HCN, Nitric Acid**
- **Screening for TIC's, TIM's & CWA's**
- **Chemical manufacturing** – Methyl Bromide, Chloropicrin, Vikane,
- **Refinery Toxics** – Benzene, Styrene, Aldehydes, Hexane, Methanol, Carbon Disulfide
- **Semiconductor Plants** – Arsine, Phosphine, Silanes, Boron
- **Hospitals** – Formaldehyde, Hydrogen Peroxide, Ethylene Oxide, Peracetic Acid
- **IAQ investigations**
- **LEED certification**

Case Study :

Identify the Unknown

Hospital lab. staff evacuated after chemical leak



Region 2 South TSRT Coordinator, was notified of a potential gas or vapor leak in the Human Pathology Laboratory at St. Joseph Hospital, MI.

"We were advised that the **suspicion was increased levels of Formaldehyde**. We ran tests in five different work areas within the lab. With the FTIR gas analyzer we were able to simultaneously test for 50 different gases/vapors using quantitative and qualitative analysis. **The results of our tests revealed that the substance was Toluene and not Formaldehyde.** The levels were well within safe limits of all found substances as well as TWA's [Time Weighted Averages]"

"**The FTIR Gas Analyzer performed flawlessly and proved it's capability beyond doubt.** The TSRT had a successful training deployment and had many educational benefits from the experience." Bob Lovelace _ Region 2 South TSRT Coordinator

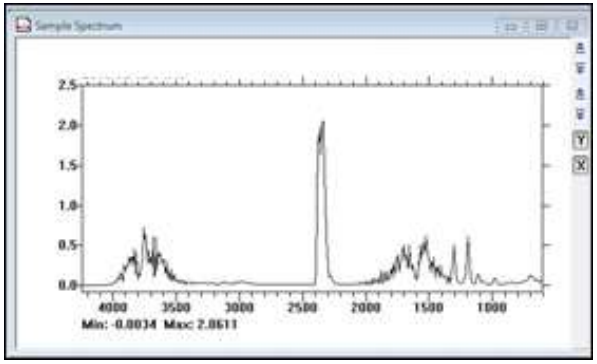
Case Study

Identify the Unknown

FREON LEAK GOES UNDETECTED AT A “TEXAS UNIVERSITY”

Analysis Results - GAS-LIB-004_SN112203_c11_11_Rev1.LIB: spe_000392.spe

Ch	Component	Concentration	Unit	Range	Resid...
1	Water vapor	0.62	vol-%	3	0.0004
2	Carbon dioxide	674.13	ppm	2000	0.0014
3	Carbon Monoxide	0.00	ppm	200	0.0015
4	Nitrous Oxide	0.30	ppm	100	0.0008
5	Sulfur Dioxide	0.00	ppm	100	0.4425
6	Nitrogen Dioxide	2.06	ppm	50	0.0022
7	Methane	1.84	ppm	100	0.0103
8	Formaldehyde	0.25	ppm	50	0.0010
9	Toluene	0.00	ppm	200	0.0101
10	Ammonia	2.93	ppm	50	0.0824
11	Hydrogen Chloride	0.00	ppm	50	0.0022
12	Hydrogen Fluoride	0.00	ppm	50	0.0006
13	Hydrogen Cyanide	0.00	ppm	50	0.0005
14	Arsine	0.01	ppm	50	0.0013
15	Phosgene	0.18	ppm	50	0.0020
16	Acrylonitrile	15.67	ppm	50	0.4521
17	Ethylene Oxide	0.15	ppm	50	0.0005
18	Boron Trichloride	0.00	ppm	50	0.4521
19	Phosphine	0.00	ppm	50	0.4671
20	Acrolein	0.00	ppm	50	0.0031
21	Methyl Mercaptan	32.35	ppm	200	0.0059
22	Carbon Disulfide	0.82	ppm	200	0.0009
23	Sulfuryl fluoride	0.00	ppm	50	0.4381
24	Dichloromethane	0.00	ppm	200	0.4495
25	Benzene	0.00	ppm	50	0.0144
226	Cell temperature	28.00	°C	40	0.0000



DX4040 Search results

Library Search Results

Library	Component	Fit	Concentration
LibrarySearch_DX4030&40_c11_11_Rev4.LIB	Freon 134A	97.79	30.65

Freon 134A

30 ppm

ASSESSING WORKER EXPOSURE & SAVING ENERGY / MONEY – PRESENTATION AT I2SL

Case Study :

(INTERNATIONAL INSTITUTE FOR SUSTAINABLE LABORATORIES)

The Lab Inhalation Risk Assessment (LIRA) study is currently in development and is expected to be a key safety and efficiency component of Harvard University Lab Ventilation Management Plan.

The challenge of the LIRA study is to use a new portable technology [Gasmet DX4040 FTIR Gas Analyzer] in the development of a process for quantifying potential inhalation exposures in the labs.

The goal of the project is to use LIRA as a method for reducing general lab ventilation rates from six air changes per hour when occupied, down to four air changes when occupied and two air changes when occupied, in spaces where the Harvard ventilation guidelines are the driving factor of the air change rates.

Case Study :

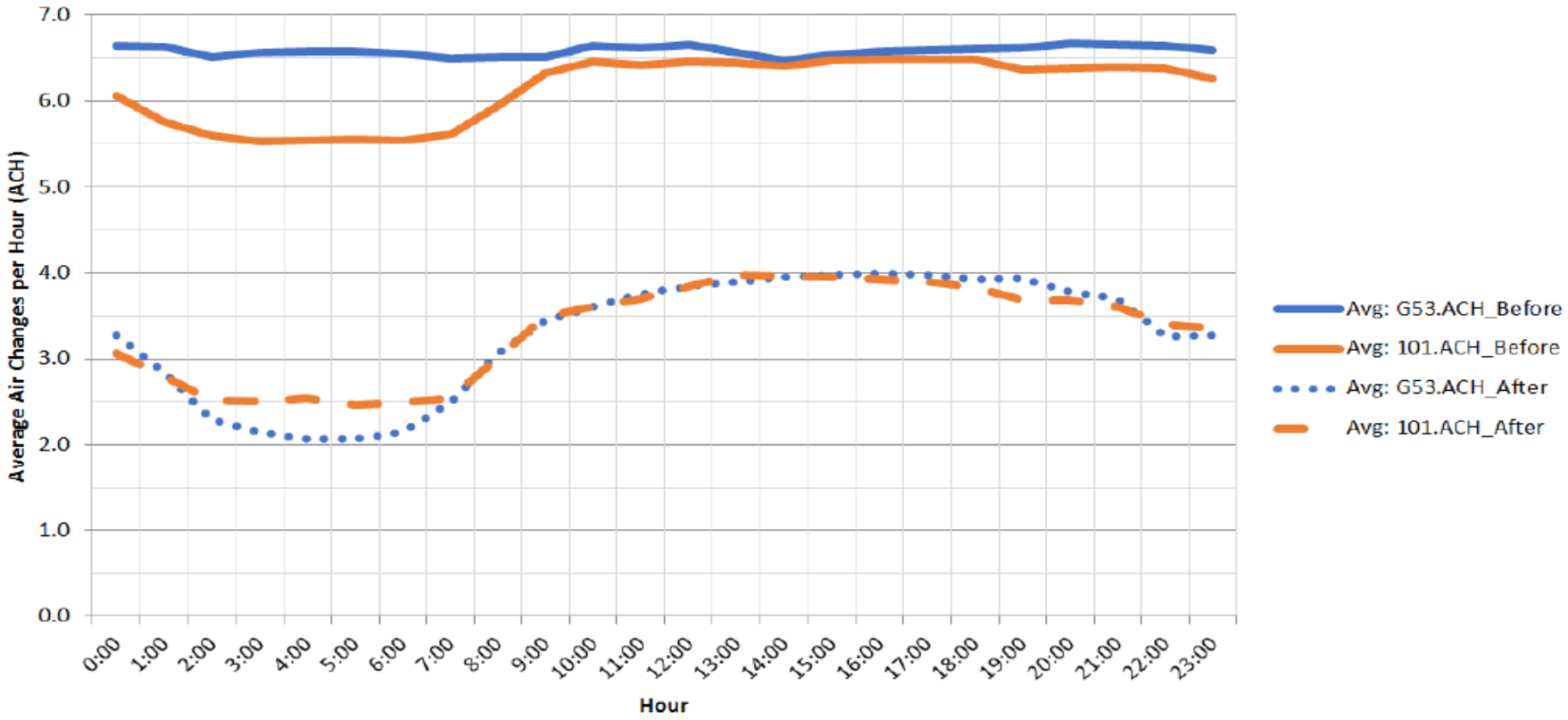
Field Study Plan

Steps:

1. Master using the Gasmet DX4040 for lab applications and identify participating labs.
2. Collect air samples throughout the labs under normal working conditions at the current ventilation rate. (6 air changes per hour)
3. Assess air quality generally, as well as during certain research processes.
4. Lower ventilation rate to 4 ACH occupied 2 ACH unoccupied and reassess.
5. Measure changes in building energy use.
6. Define acceptable ambient lab air quality.

Case Study :

Results



Results & Next Steps

Case Study :

Results for first test period of July 2018 vs August 2018

1. Supply and Exhaust Fan Electrical Energy Change
   a) Fan CFM reduction resulted in 15% kWh cost reduction (6% of total bill)
   b) 1 Month Net savings of $3,089

2. Airflow Energy Change (normalized for CDD)
   a) Supply side increased by 0.14%
   b) Exhaust side decreased by 0.15%
   c) 1 Month Net savings of $49

3. **Projected Annual Savings: $37,680**
   - **For only for 65% of available Open Lab Spaces** (22% of gross building area)

Next Steps – deeper analysis of HVAC system performance at the new operating parameters

UTILITY COMPANY FUNDING FOR ENERGY SAVINGS

Harvard partnered with Eversource on this project with a goal of saving energy.

Eversource funded part of the purchase of the Gasmet unit.

Eversource is working closely with Harvard to quantify the energy savings, and looking at developing an incentive program based on the results of the Harvard LIRA results.

This would be similar to existing incentives for other commercial energy savings – steam trap surveys and repairs, compressor surveys and upgrades, etc.

DIACETYL MONITORING IN COFFEE ROASTING

Case Study :

30 compounds measured due to the complex matrix

NIOSH Sampling alongside FTIR Gas Analysis

Diacetyl and 2,3-Pentanedione in Breathing Zone and Area Air During Large-Scale Commercial Coffee Roasting, Blending and Grinding Processes

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John Greivell[d]

gasmet > Know what's in the air.

HEALTHCARE FACILITIES –
COMPLETE MONITORING SOLUTION FOR TOXIC GASES

1. Operating & Recovery Rooms
WAG's – Desflurane, Nitrous Oxide, Sevoflurane, Enflurane, Isoflurane

2. Toxic Sterilant Gases
a). Formaldehyde
b). Hydrogen Peroxide
c). Ethylene Oxide
d). Peracetic Acid

3. ED - Screening contaminated patients (Identify the Unknown)

Testing for **Post-Fire Toxic Gases**

"Removal of respiratory protection during fire overhaul activities or in the general area can expose firefighters and fire investigators to an **unknown variety of toxic chemicals** and particulates."

Chemical Exposures	OSHA TWA PEL (ppm)	# Fires Analyzed	# fires found
Acrolein	0.1	11	4
Aldehydes (total aliphatic)	n.d.	29	19
Ammonia	50	29	8
Benzene	1	29	10
Benzyl chloride	1	12	3
Carbon disulfide	30	3	3
Carbon monoxide	50	38	30
Formaldehyde	0.75	29	4
Furfural	5	3	3
Glutaraldehyde	n.d.	12	12
Hydrogen chloride	5	37	8
Naphthalene	10	37	7
Nitrogen dioxide	3	37	28
Nitrogen monoxide	25	29	28
Ozone	0.1	29	21
Phenol	5	29	9
Sulfur dioxide	5	29	2
Styrene	100	29	25
Toluene	200	29	27

A portable FTIR Gas Analyzer can quickly test for these gases and alert firefighter if site is clear to remove SCBA.

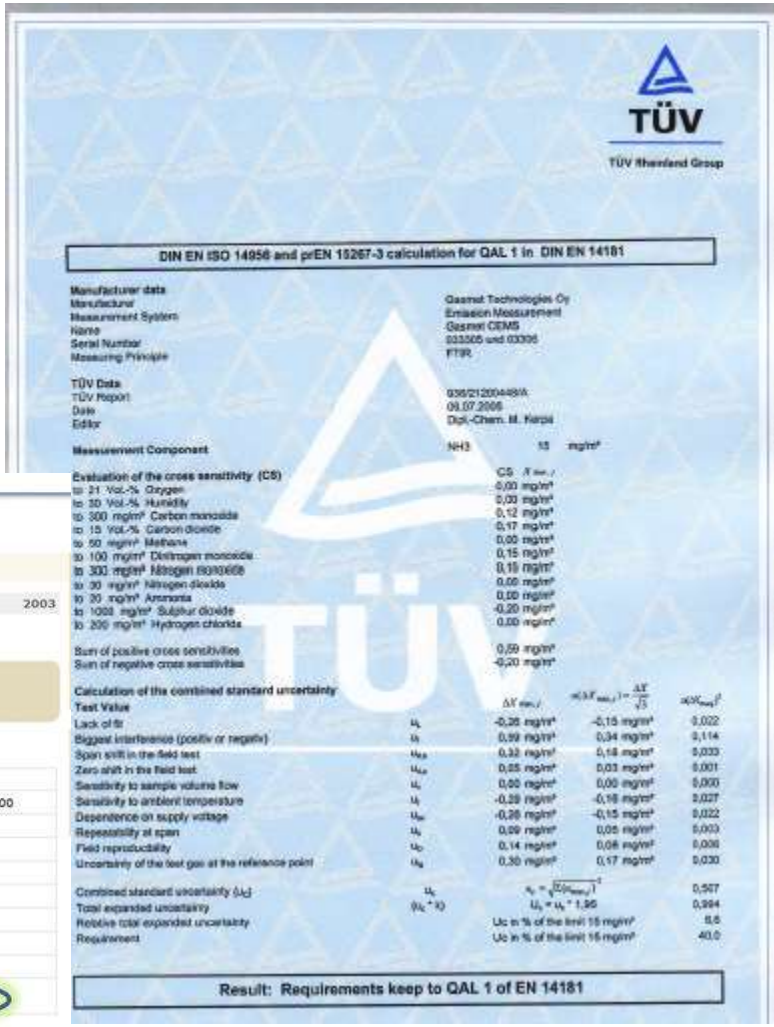
Paper by_Deric C. Weiss and Jeff T. Miller Tualatin Valley Fire & Rescue 2011

FTIR VALIDATION & CERTIFICATION

FTIR Methodology accepted by leading test organizations including :

- **NIOSH** Method 3800 (Organic & Inorganic gases by extractive FTIR spectrometry)
- **USEPA** Method 320
- **ASTM** Method D6348

- TUV & MCERTS 3rd party verification



QUESTIONS?

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